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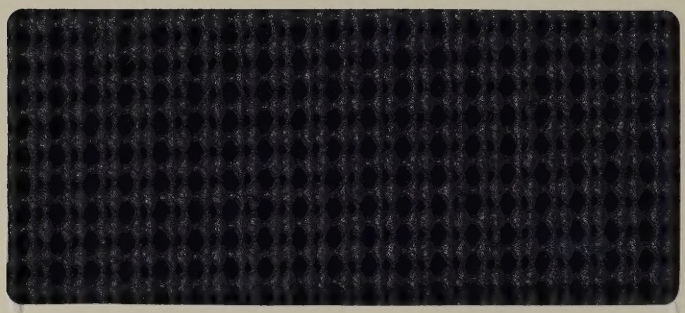
SUPPLEMENTARY HYDROGEOLOGICAL AND SOILS STUDY, SANITATION, INC. LANDFILL LEWISTOWN, MONTANA

RECEIVED
APR 0 7 1995
Montana Department of Health
and Environmental Sciences
Waste Management Division

D&A DAMSCHEN & ASSOCIATES, INC.
CONSULTING ENGINEERS
• HELENA, MONTANA •



SUPPLEMENTARY HYDROGEOLOGICAL AND SOILS STUDY, SANITATION, INC. LANDFILL LEWISTOWN, MONTANA

April, 1995

Prepared for:

Sanitation, Inc., Lewistown, Montana

Prepared by:

Damschen & Associates, Inc.
Helena, Montana

INTRODUCTION

Purpose and Scope

The purpose of this study was twofold. First, Damschen & Associates, Inc. was retained to oversee the completion of a Hydrogeological and Soils Study in order to bring the Sanitation, Inc. landfill into compliance with the current rules of the State of Montana Department of Health and Environmental Sciences (DHES) Waste Management Division. Second, Damschen & Associates, Inc. was to evaluate the facility to determine the feasibility of installing a vadose monitoring system in lieu of a ground-water monitoring system. These two tasks were completed in conjunction with the installation of methane monitoring wells at the landfill.

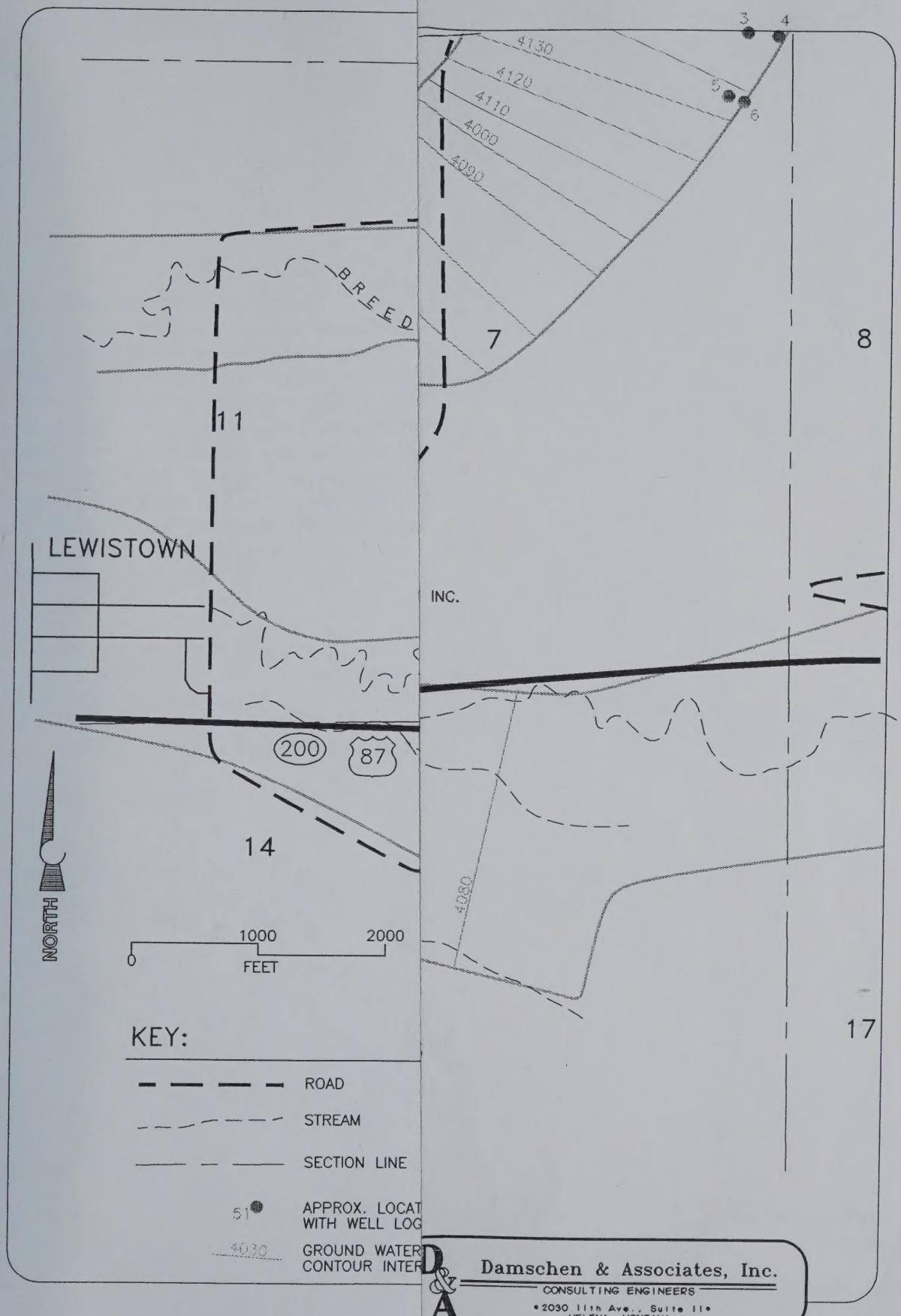
This report summarizes the hydrogeological and soil aspects of the site and the related monitoring installations. The completion logs of the methane monitoring well installations along with the methane testing results will be available under separate cover.

Location and Description

The Sanitation, Inc. landfill site is located about 1.5 miles east of the City of Lewistown in the southwest ¼, southwest ¼, Section 7, Township 15 North, Range 19 East (Figure 1). It is accessible via Highway 87 (S.R. 200) from Lewistown. The facility is situated atop an elongated ridge that acts as a drainage divide between Boyd Creek to the south and a tributary of Breed Creek to the north (Figure 1).

Previous Work

Geological investigations of the region extend back to the turn of the century, but few recent studies encompass the area in the immediate vicinity of the landfill. No comprehensive ground-water studies have been undertaken in the area, but many well logs are available for interpretation. An attempt to represent the regional hydrogeology was presented in the Work Plan submitted to the Waste Management Division early in January, 1995. Maps of the regional and valley-fill aquifers constructed from existing well logs were submitted in that report, and are included here as Figures 2 and 3. However, the reader should refer to the Work Plan document for details of the geology, hydrology and previous work conducted at the facility. In addition, the reader should refer to the Methane Monitoring Plan submitted to the Department in December, 1994.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Damschen & Associates, Inc.
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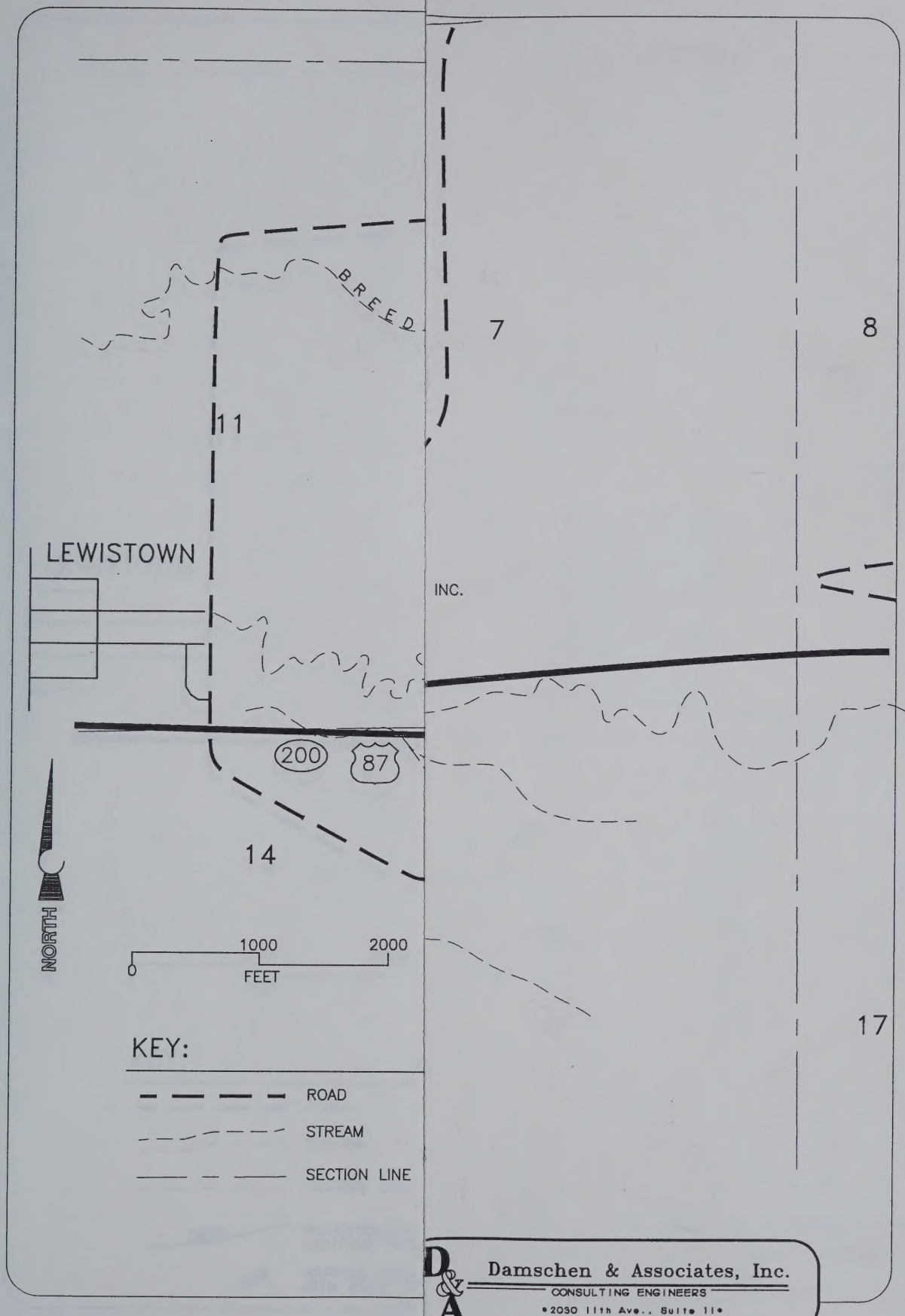
•HELENA, MONTANA•



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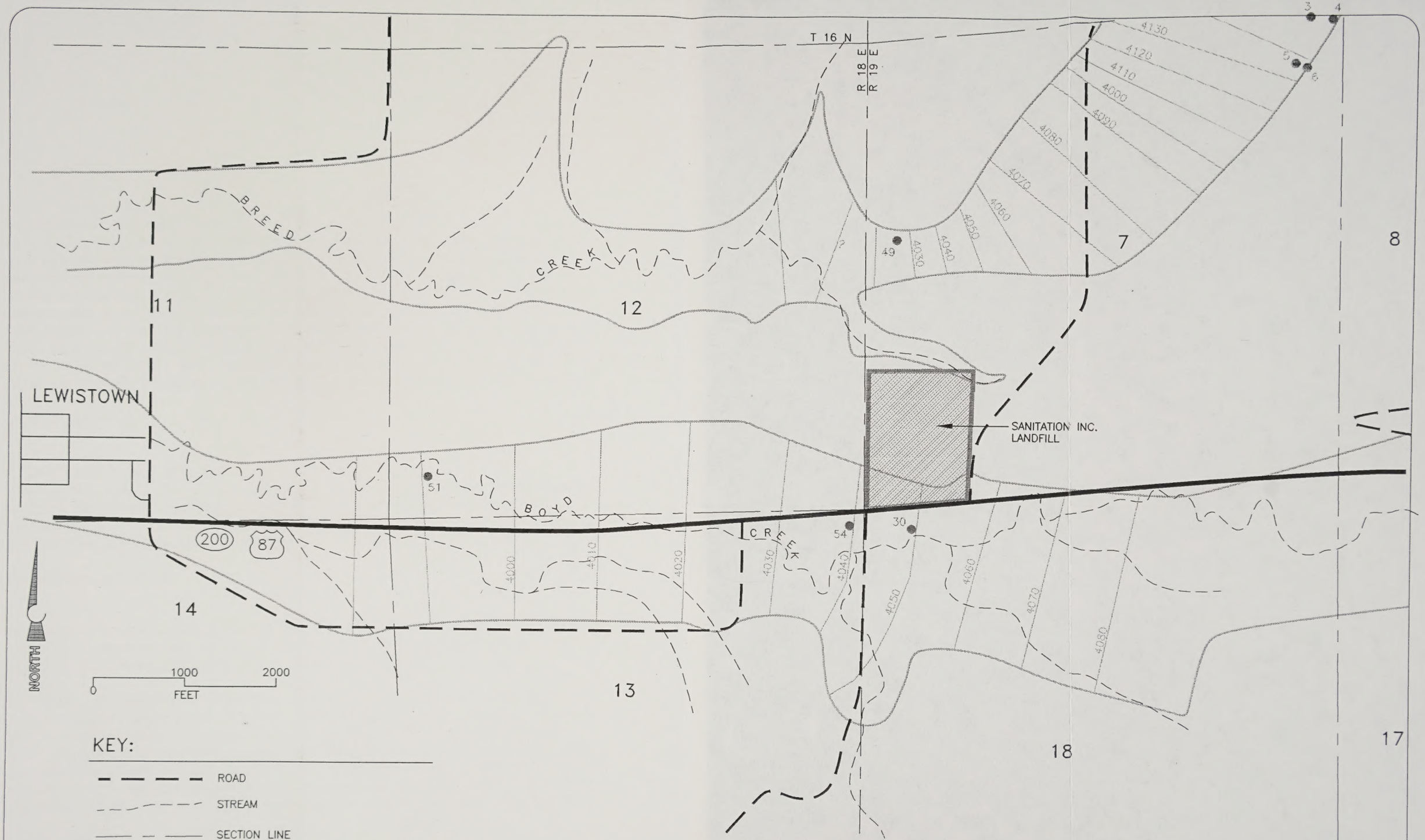

Figure 2. Map of valley - Fill aquifers east of Lewistown, Montana

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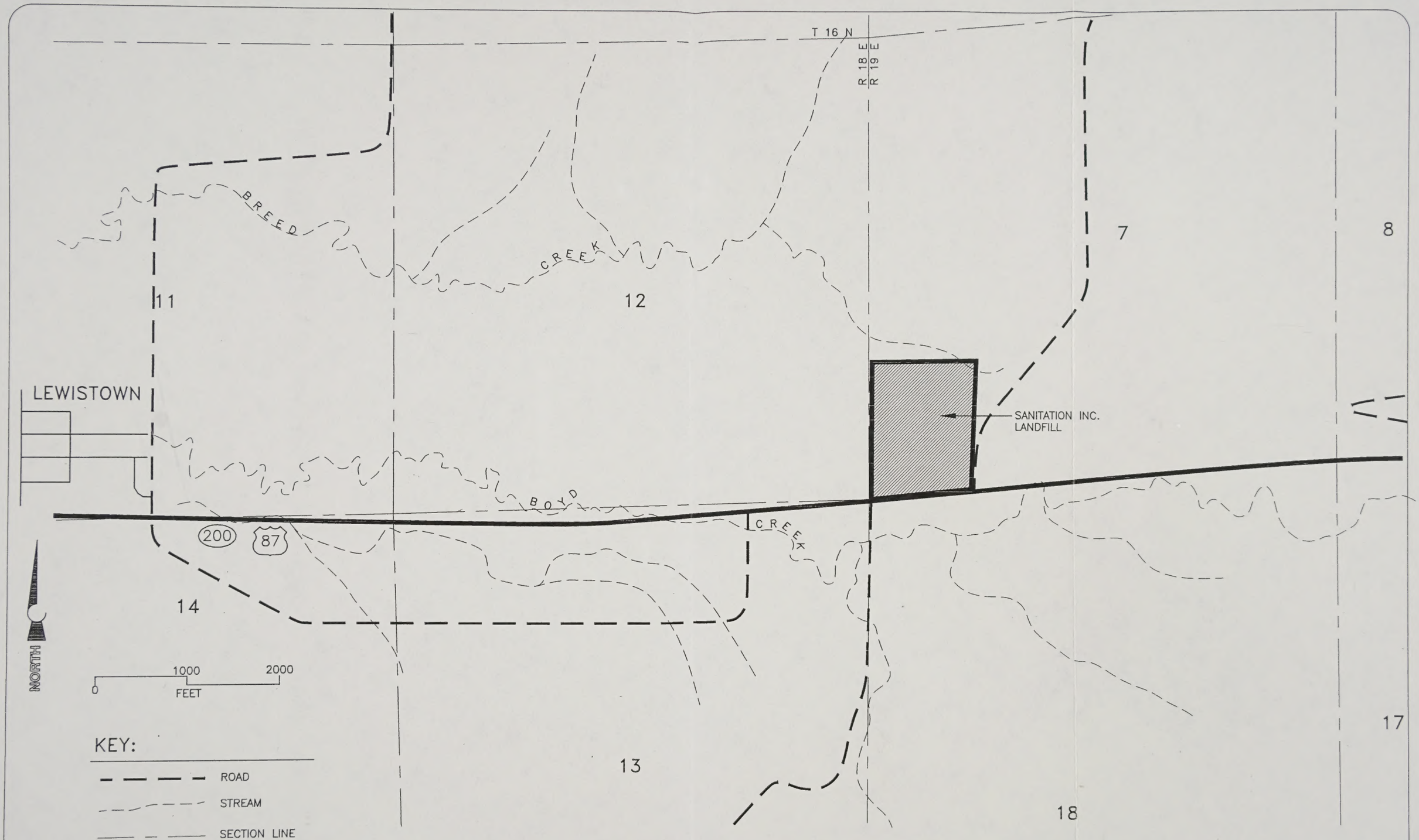

Figure 1. General location of the Sanitation Inc. landfill Lewistown, Montana

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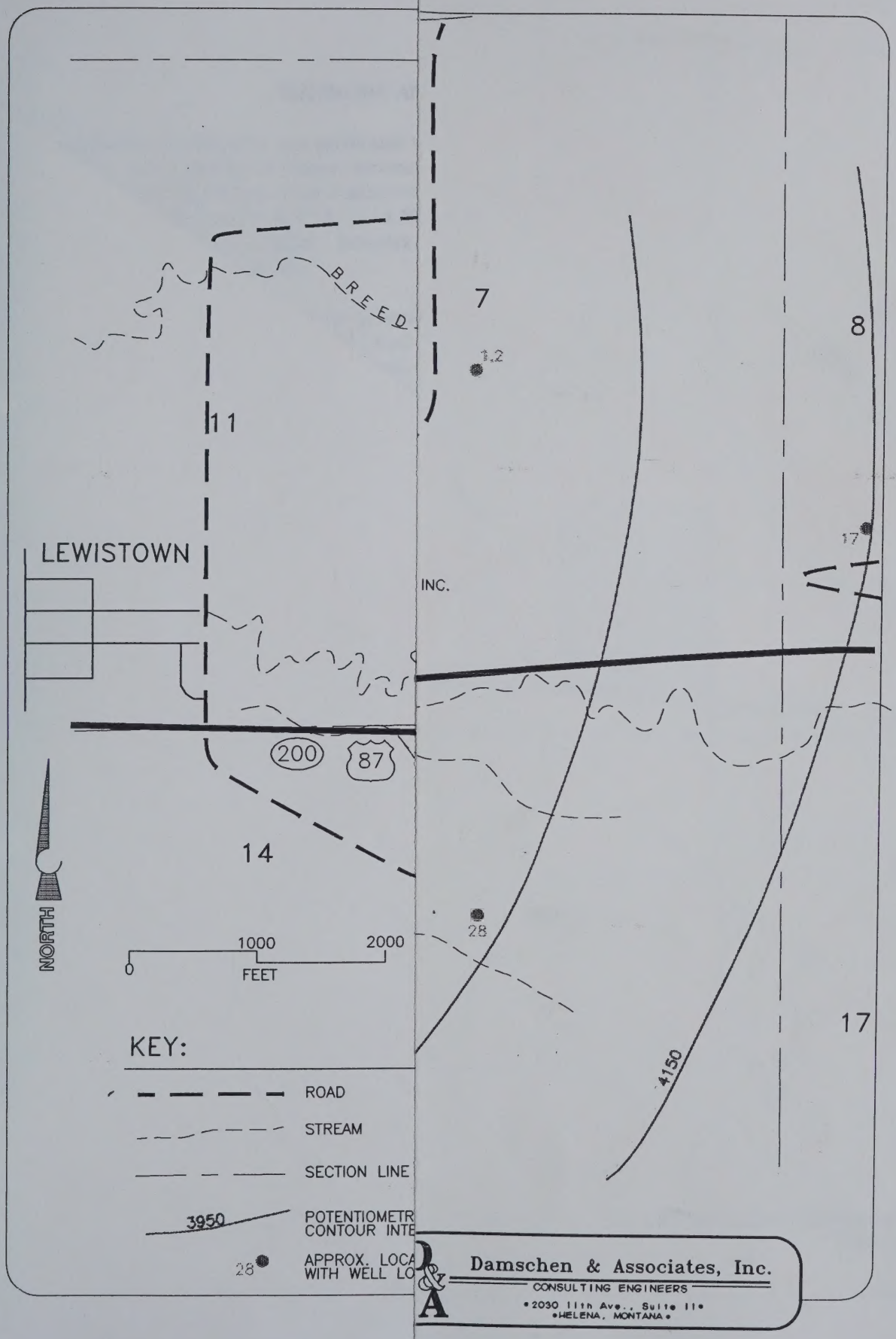
BREED
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•2030 11th Ave., Suite 11•
•HELENA, MONTANA•

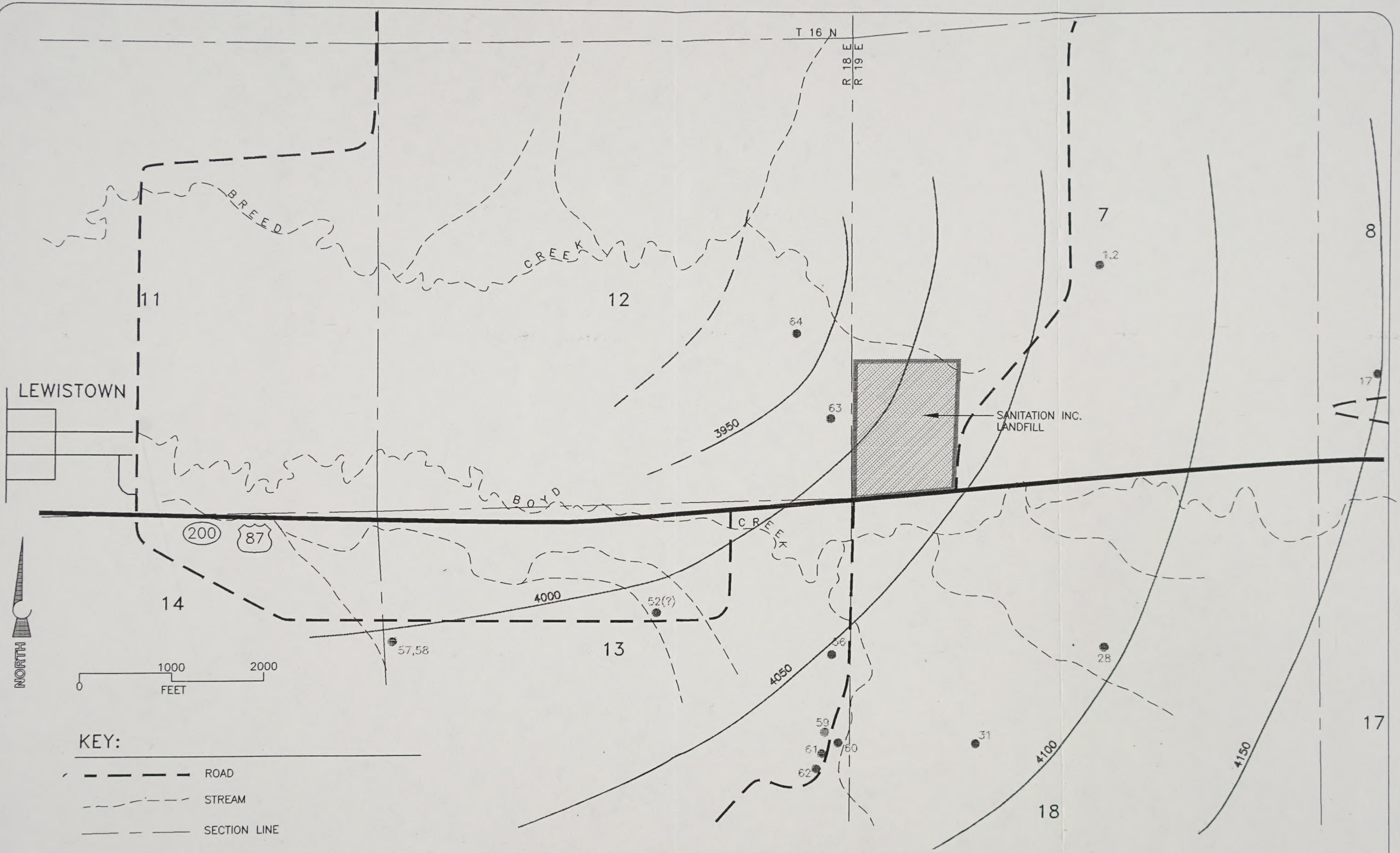

Figure 3. Potentiometric map of Regional Aquifer East of Lewistown, Montana

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CONSULTING ENGINEERS
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•HELENA, MONTANA•

METHODS AND MATERIALS

The sub-surface investigation was performed with a Gardner-Denver table-drive air rotary rig provided by Sharp Drilling of Sidney, Montana, MWL 235. All drilling and the completion of all sub-surface installations were conducted according the requirements and recommendations outlined in A.R.M. 16.14.706 and A.R.M. 36.21.700. Drilling equipment was decontaminated between holes. Samples were collected continuously from the cuttings and bagged on five-foot intervals.

Because the material being drilled was generally well-lithified, fine-grained sedimentary rocks, grain-size analysis was of questionable value, so no samples have been submitted for physical analysis to date. Samples are being retained, however, should the need for physical analysis arise in the future.

RESULTS AND DISCUSSION

Summary of Field Work

Drilling was initiated at the landfill after approval was received from the Waste Management Division for the installation of four methane monitoring wells and the installation of a vadose zone monitoring system. In order to aid in the geological evaluation of the facility, the decision was made to over-deepen some of the methane monitoring wells. This would allow for a reduction in the footage required for a complete analysis of the site, and still allow for the appropriate installation of the requisite monitoring devices.

The first hole was drilled near the toe of the active trench, as indicated on the accompanying figure (Plate 1), and was intentionally located in the general vicinity of the proposed methane monitoring well SIG-1 as designated on the Methane Monitoring Plan map. Noticeably wet sediments were returned from this hole at a depth of about 36 feet. The drill was shut down, and after about 15 minutes free water could be blown out. The hole was deepened only a few feet until dry carbonaceous shale was returned, indicating that the water encountered was perched within a sandy zone atop a stratum of clay shale.

The hole was completed as a piezometer in order to measure the ground water elevation. It was finished with 1.25-inch diameter Schedule 80 PVC casing with a four-foot hand-slotted screen. A filter pack of 10/20 Colorado silica sand was installed to one foot above the screen and the hole was sealed with medium chip bentonite to the water level. The remainder of the hole was sealed with #8 granular bentonite, and the riser was covered with a four-inch-square locking steel protective cover. This piezometer has been labelled SIP-1, and the last measurement taken showed the top of the water table to lie at an elevation of about 4,085 feet above mean sea level (MSL).

Because a good deal of water and wet sediments were blown out of the hole, it was not deemed advisable to install a methane monitoring well in this boring. The very fine-grained sediments being drilled would likely seal off any fractures or primary porosity through which the methane might migrate, rendering the installation of wells useless. Therefore, the drill rig was simply moved a few feet and another shallow hole was drilled to the depth of the uppermost clay stratum. The methane well SIG-1 was installed in the second hole and completed as indicated on the attached well log.

Water had not clearly been detected in other test borings drilled west of the facility in October of 1993, making the discovery of water at SIP-1 unexpected. The previous test borings had shown a north-northwesterly dip to the strata, so the scope of the investigation was altered to include a search for a recharge zone to the east or southeast, which, given the elevation of the water discovered at SIP-1, was the only logical choice. Examination of the topography on the northeastern edge of the facility revealed a very likely recharge zone in the form of a relatively flat, dendritic drainage leading westward into the steep dry gulch that borders the

landfill to the north. This area appears to be underlain by the same grey clay shale as seen across from the shop located at the landfill entrance. A methane well was scheduled to be installed along the northern border of the facility at the location labelled on the Work Plan map as SIG-4, so a boring was advanced near this location just south of the newly-installed fence. As noted on the attached log, moist sediments were encountered at a depth of 52 feet below ground level. The aquifer at this location does not appear to make as much water, perhaps because it is on the edge of the aquifer. This boring was also outfitted with a piezometer as described in the attached well log for SIP-2.

Again, because of the coating of wet, fine-grained sediments lining the hole, the drill rig was simply moved forward a few feet for the drilling and installation of the relatively shallow methane monitoring well SIG-4. The construction details of this installation is described in the attached well log.

Drilling at the remaining two proposed landfill gas monitoring well locations did not reveal the presence of any water. In fact, the water table elevation at SIP-2 is more than five feet above the ground elevation at the shop and office, and the discovery of water was not anticipated at either of these locations. Both SIG-2 and SIP-3 were over-drilled in order to test for the presence of water, and, with no water being detected, were back-filled with a combination of cuttings and #8 bentonite to the level required for the installation of the methane monitoring well. Please note that SIP-3 was drilled to below the general elevation of the valley floor proximal to the landfill to the south.

In an attempt to more closely delineate the extent of the newly-discovered aquifer a test boring was drilled south of the piezometer SIP-2. This hole, designated as SI-5, was collared within well-lithified silty sandstone at an elevation of about 4,127 feet MSLD and was drilled to a depth of 40 feet.

Hydrological Characterization

The ground water discovered at the Sanitation, Inc. landfill can be characterized as a relatively small, low-production, perched aquifer that is recharged locally. The recharge area is most likely the small drainage that bounds the northeastern edge of the landfill, and the direction of flow appears to be generally to the northwest. This is not specifically clear, because only two piezometers were installed, and three are required to define the direction of the dip of the hydraulic gradient. It is highly unlikely that Boyd Creek, which lies south of the facility, has much effect on this aquifer. First, the static water levels measured at the landfill lie almost 20 feet above the Boyd Creek valley, and 30 to 40 feet above the top of the alluvial aquifer water table. It seems unlikely, too, that the water moves toward Boyd Creek because the sedimentary strata that host the aquifer clearly dip to the northwest at an angle of about three to five degrees. The aquifer could not be found in any location south of SIP-1 and -2. Therefore, it can be concluded that the aquifer is truly perched and discontinuous to the south.

This appears to be an open or water table aquifer, but may be confined further to the northwest as it moves down-dip along the stratum that acts as the aquifer host. The aquifer lies within fine sand and fractured silty sandstone and is perched atop a stratum of black clay shale. The discharge point of the aquifer is not known at this point in time. If the northwesterly direction can be confirmed, then discharge may be to Breed Creek.

The flow characteristics of the aquifer have not been tested, because the appropriate installations have yet to be completed: the piezometers installed to date probably do not have adequate screened intervals. The screens were cut by hand and were intended only to allow for the measurement of water table elevations. From a qualitative point of view, however, it is likely that the formation hosting this aquifer is apt to be fairly transmissive. The water-bearing formation includes medium sand and sandstone.

Preliminary observations indicate that the aquifer has no resource value in the immediate vicinity of the landfill. It is likely not to have a great resource value, if any, at any distance from the facility. This conclusion is a result of the relatively small recharge area.

The chemistry of the ground water has not yet been characterized, but upon the installation of more appropriate monitoring wells, ground-water samples will be submitted to a qualified laboratory for Table 1 parameter analysis. In addition, a number of additional parameters will be added, including major ions, total dissolved solids, and ammonia nitrate.

Recommendations

It would appear that Sanitation Inc. should install ground-water monitoring wells and begin a program of semi-annual sampling. There are several reasons for this conclusion, the primary one being the separation distance between the base of the active cell and the top of the aquifer. This distance exceeds 50 feet vertically in most places, but the depth may be less because the stratigraphic horizon (the black clay shale) that holds up the perched aquifer essentially dips parallel to the base of the landfill cell. It is probable that only the lower "toe"of the active cell lies directly over the aquifer. This aquifer has little or no resource value in the vicinity of the landfill, but should be monitored as a "first line of defense" for the protection of deeper-lying, more valuable water resources.

The cell currently in use was cut through fractured siltstone and sandstone, which was initially a point of concern regarding the migration of fluids. Moisture moving through a landfill cell can move through vertical fractures very quickly. Drilling results have shown that the material underlying the cell is more clay-rich than initially thought and not very well indurated. This means that fractures do not present as many potential pathways for leachate migration as initially suspected. Some modest laboratory testing of the soils will be undertaken to quantify the clay content of this soil, and the results will be reported as soon as they are received.

The landfill area does not provide a very large or effective recharge of water to the uppermost aquifer at this site, but some recharge probably occurs from time to time. Thus, there is a potential for the waste to provide a source of contaminants to the aquifer and it is only prudent that a sampling program be undertaken.

As noted previously, water was discovered unexpectedly at this facility. Because of the changes in monitoring tactics that were certain to result from this discovery, it was deemed most prudent to evaluate the data collected and develop a revised work plan. Having had the opportunity to examine the data, it becomes clear that one or two details of the ground-water characterization need to be confirm before a monitoring plan may be implemented. Prior to the installation of any monitoring wells at least one additional test boring should be drilled along the road between SI-5 and SIP-2 in order to determine the southerly extent of the aquifer. The test boring should be drilled to a depth that insures that the bottom of the hole lies well below the lowest aquifer elevation observed at SIP-1. Assuming that the hole is collared at an elevation of approximately 4,135 feet MSL, the total depth should be 80 feet, which would put the bottom of the hole at 4,055 feet. This would be 30 feet below the static water level at SIP-1 and about 40 feet below the static water level measured at SIP-2. This elevation would also be below the static water level in the Breed Creek valley fill aquifer south of the facility. If water is encountered, it is recommended that a small-diameter well (piezometer) be installed for the purposes of water table measurements.

Another hole needs to be drilled toward the central portion of the northern side of the waste fill area at either of the locations noted on Plate 2. Drilling will likely encounter the aquifer at depths of 45 to 55 feet in this area, and either location would be appropriate for the installation of a ground-water monitoring well.

The most difficult decision involved with ground-water monitoring at this facility will be determining an appropriate location for a background well. If the direction of flow and the recharge zone can be confirmed as anticipated, then siting the well may not be difficult, but actually finding a saturated zone to monitor may present a problem. That is, if the recharge zone is the low-lying area to the east of the landfill, the closer to that area one looks, the less likely it is that sufficient water will be encountered in the aquifer.

Damschen & Associates, Inc. recommends that the final phase of this investigation be the installation of three ground-water monitoring wells. These wells can be installed at essentially the same locations as three of the proposed vadose monitoring installations, specifically in the vicinity of the two existing piezometers and at a location between them along the northern perimeter of the facility. The locations will have to be determined on the basis of information collected to date and the additional data gathered during the final phase of drilling. Again, the working hypothesis here is that the aquifer is confined within northward-dipping strata and is recharged by infiltration into a small drainage area that lies northeast of the existing landfill. Additional constraints involve the location of waste in relationship to the facility boundaries and topographic limitations involved with siting a drill rig. Thus, at this point in time it is assumed that a background well will probably be installed about 100 feet northeast

of SIP-1, and down-gradient wells will be completed near SIP-1 and at any accessible point along the north-central edge of the waste fill.

CONCLUSIONS

The Sanitation, Inc. landfill east of Lewistown, Montana is underlain by generally fine-grained sediments of the Kootenai formation and the Colorado group. These rocks dip gently to the northwest, in concordance with the regional structure. A sandstone stratum was discovered to contain water along the northern boundary of the landfill. This aquifer could not be found to the south, and its southern boundary probably lies on the order of a hundred feet or less from the piezometers labelled SIP-1 and -2. The recharge zone for the aquifer is likely the low-lying area that lies northeast of the landfill. This recharge area appears to be underlain by a fairly thick carbonaceous clay shale that is probably related to the Colorado group shales, making for an efficient trap for the collection of surface runoff.

This discontinuous aquifer may well interact with other, deeper-lying aquifers off of the property, and should be the target for the ground-water monitoring program. If the working hypothesis described above proves correct, it may be feasible to install a single background well and two down-gradient wells within the licensed facility boundary. The installation of these wells will be dependant upon the interpretation of the data gathered from drilling one or two additional test borings to be drilled in conjunction with the network installation.

The ground-water monitoring wells should be sampled immediately upon completion and development. The samples should be analyzed for the ARM 16.14.706 Table 1 constituents as well as for major ions, ammonia nitrogen and total dissolved solids.

REFERENCES

Calvert, W. R., 1909, Geology of the Lewistown coal field, Montana: U.S. Geological Survey Bulletin 390, U.S. Government Printing Office, Washington, D.C.

Damschen & Associates, Inc., 1995, Work Plan for the Sanitation, Inc. landfill, Lewistown, Montana: unpublished work plan and hydrogeological summary submitted to the Montana DHES Waste Management Division, Helena, Montana, 19 pages, 1 plate.

Appendix A. Drilling logs and completion details of piezometers, methane monitoring wells and test borings at the Sanitation, Inc. landfill, Lewistown, Montana.

Plate 1. Site plan of the Sanitation Inc. landfill, Lewistown, Montana.

DAMSCHEN & ASSOCIATES, INC.
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P.O. BOX 4817 • HELENA, MT 59604

TELEPHONE (406) 449-8627
FAX (406) 449-8631

April 10, 1995

Ms. Pat Potts
MDHES Waste Management Division
P.O. Box 200901
Helena, MT 59620-0901

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and Environmental Sciences
Waste Management Division

Dear Ms. Potts:

Enclosed please find the logs for the wells and test borings completed at the Sanitation, Inc. landfill in Lewistown. They were inadvertently omitted from the report submitted to you on April 6, 1995. I apologize for any inconvenience this may have caused.

Sincerely,

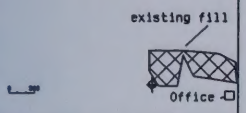
DAMSCHEN & ASSOCIATES, INC.

Bruce L. Siegmund
Project Hydrogeologist

Enclosures
CC: Sanitation, Inc., Lewistown, Montana

Boring Name: SI-1

Job Number: 93-51
Client: Sanitation, Inc.
Date: unknown
Drilling Method: Air Rotary
Drilling Firm: unknown
Total Depth: 155 ft.
TOC Elevation:
Geologist:



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Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
0–22		tan sandy siltstone, moderately well-lithified; cuttings show slightly higher sand content with depth
22–24		grey clay shale
24–32		interbedded sand and silt, with sand fraction increasing w/ depth
32–45		predominately fine-grained tan sand with significant silt fraction
45–50		tan sandy siltstone

4140
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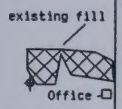
Waste Management Division



Boring Name: SI-1

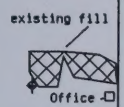
Job Number: 93-51
Client: Sanitation, Inc.
Date: unknown
Drilling Method: Air Rotary
Drilling Firm: unknown
Total Depth: 155 ft.
TOC Elevation:
Geologist:

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
55		grey clay shale
70		greyish green calcareous sand and silt, fining with depth
80		greyish green calcareous silt
85		very fine-grained silty sandstone
90		greyish green sand, very fine-grained, calcareous
95		tan sandstone, well-lithified, some thin bedding planes visible in cuttings
100		

4090
4085
4080
4075
4070
4065
4060
4055
4050
4045



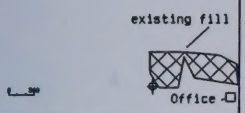
Boring Name: SI-1

Job Number: 93-51
Client: Sanitation, Inc.
Date: unknown
Drilling Method: Air Rotary
Drilling Firm: unknown
Total Depth: 155 ft.
TOC Elevation:
Geologist:

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description	Elevation
			4040
105			
			4035
110		rust to maroon clay shale	
			4030
115			
			4025
120			
			4020
125			
			4015
130			
			4010
135		grey clay shale	
			4005
140			
			4000
		rust to maroon clay shale; driller injected water (verbal communication, landfill operator)	
145			
			3995
150			



Boring Name: SI-1

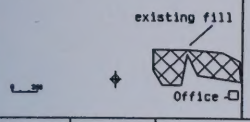
Job Number: 93-51
Client: Sanitation, Inc.
Date: unknown
Drilling Method: Air Rotary
Drilling Firm: unknown
Total Depth: 155 ft.
TOC Elevation:
Geologist:

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
155		
160		
165		
170		
175		
180		
185		
190		
195		
200		

3990
3985
3980
3975
3970
3965
3960
3955
3950
3945



Boring Name: SI-2

Job Number: 93-51
Client: Sanitation Inc., Spoja
Date: 10/5/93
Drilling Method: Air Rotary
Drilling Firm: Four Star Drilling, Lewistown
Total Depth: 220 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
		topsoil: light brown to tan sandy loam
5–15		tan silty sand and siltstone; siltstone is fairly resistant; some grey shale beds at 10 to 15 feet; Cretaceous Kootenai formation (Kk).
20		maroon to rusty brown clay shale; bit dropped quickly; poor return
25–30		tan to greyish tan sandstone; well lithified, fine grained, slightly iron stained in places; poor return, probably due to strong fracturing or blow-outs in overlying sandstone
35		sandstone, as above, well lithified
40		loose sand, poor return
45–50		sandstone, as above, well lithified, poor return

4120
4115
4110
4105
4100
4095
4090
4085
4080
4075

Boring Number B3-2

Job Number 93-02
Client Swallow Bld. Depts
Date 6/15/93
Drilling Method Air Rotary
Drilling Firm Five Star Drilling Lewiston
Total Depth 220 ft
Rig Elevation
Geologist Sigmund

Location Plan

Depth (ft) | Sample No. | Description

Topsoil, light brown to tan sandy loam

Tan silty sand and medium plasticity to fairly resistant, some dry thick beds at 10 to 12 feet Cretaceous Kootenai Formation (Kk)

Medium to dark brown clay sandy bit crumbed dusky poor retain

Tan to brown fine sandstone, well lithified, fine grained, slightly iron stained in places, poor texture, probably due to strong fracturing of rock mass in sampling operations

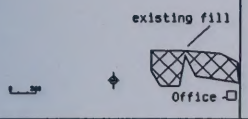
Interbedded as above, very similar

Same sand, poor retain

Sandstone, as above, well lithified, poor retain

Tolerance & Associates, Inc.
Helena, Montana

Log Description
Details



Boring Name: SI-2

Job Number: 93-51
Client: Sanitation Inc., Spoja
Date: 10/5/93
Drilling Method: Air Rotary
Drilling Firm: Four Star Drilling, Lewistown
Total Depth: 220 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

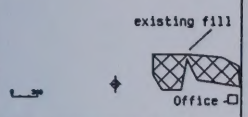
Depth	Graphic Log	Description	Well Construction Details
55			4070
60		virtually no return; material coming up the hole comprises grey dust and some small bits of grey sandstone; driller asserts that it is in sandstone.	4065
65			4060
70			4055
75			4050
80			4045
85			4040
90			4035
95		return increasing but still poor; mostly grey silt, very fine sand and dust	4030
100			4025

Boring Name: S1-2

Description

Boring Name: SI-2

Job Number: 93-51
Client: Sanitation Inc., Spoja
Date: 10/5/93
Drilling Method: Air Rotary
Drilling Firm: Four Star Drilling, Lewistown
Total Depth: 220 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
		no return
105		poor return
		dust blowing out of hole changes from grey to rusty red and maroon; probably maroon clay shale of Kk
110		
115		
120		very little return, mostly maroon shale
125		
130		
135		
140		dust changes to grey; possibly grey sandstone
145		
150		

4020
4015
4010
4005
4000
3995
3990
3985
3980
3975

Boring Number B1-2

Job Number: 87-01
Owner: Sanborn Inc. Basin
Date: 6/1987
Drilling Method: 4¼ Rotary
Drilling Fluid: Fresh Water Drilling Conditions
Total Depth: 200 ft.
Hole Diameter
Engineer: Engineer

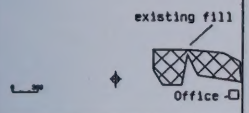
Sanborn & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Sample No.	Description
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		
130		
140		
150		
160		
170		
180		
190		
200		

Boring Name: SI-2

Job Number: 93-51
Client: Sanitation Inc., Spoja
Date: 10/5/93
Drilling Method: Air Rotary
Drilling Firm: Four Star Drilling, Lewistown
Total Depth: 220 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

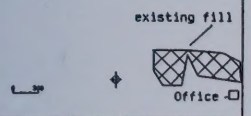
Well Construction Details

Depth	Graphic Log	Description
155		
160		very poor return; maroon dust to about 170 feet
165		
170		very poor return; grey dust to 180 feet
175		
180		no return
		grey dust; possibly grey sandstone
185		maroon shale; poor return, but some cuttings recovered
190		
195		clearly encountering moisture in maroon clay shale by 190'
200		

3970
3965
3960
3955
3950
3945
3940
3935
3930
3925

Boring Name: SI-2

Job Number: 93-51
Client: Sanitation Inc., Spoja
Date: 10/5/93
Drilling Method: Air Rotary
Drilling Firm: Four Star Drilling, Lewistown
Total Depth: 220 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
205		poor return, possibly sandstone
215		no return
220		total depth = 220 feet; production estimate impossible due to lack of return; static water level rose to 128 feet; hole plugged with 26 bags of 3/8' Hole-Plug brand bentonite pellets.

3920
3915
3910
3905
3900
3895
3890
3885
3880
3875

Boring Number SI-2

Job Number 93-31

Client Swinerton Inv. Servs

Date 10/5/93

Drilling Method Air Rotary

Drilling Firm Tom Sims Drilling Limited

Total Depth 200 ft

Soil Samples

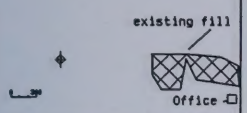
Geologist Dupreez

Elevation & Approximate Top of Hole Monitoring

Well Construction Details

Boring Name: SI-3

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: air rotary
Drilling Firm: Four-Star Drilling, Lewistown
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
0		topsoil; sandy loam, medium to light brown
5		poorly-lithified tan sandstone and loose sand, generally fine-grained and silty, some poorly-lithified siltstone and claystone fragments returned, finer material appears to occur as intercalated beds
10		
		maroon clay shale
15		grey sandstone and siltstone
		maroon shale
		grey silty sandstone, very fine-grained
20		yellowish-tan sandstone
		maroon shale
		grey siltstone and sandstone
25		rusty silt and clay interbedded with tan to grey silty sand
30		interbedded grey and pale yellow sitlstone an sandstone, poorly indurated, a few rusty strata here and there
35		
40		grey silty clay grading with depth to black arenaceous shale with a few intercalated rusty silt beds
45		
50		

Elevation
4095
4090
4085
4080
4075
4070
4065
4060
4055
4050

Boring Name: SI-1

Job Number: 93-81
Client: Sanitation, Inc., Dpcia
Date: 10/19/93
Drilling Method: Air rotary
Casing Type: Flus -Stat Casing, Lewistown
Total Depth: 250 ft.
TOC Elevation:
Geologist: Chapman

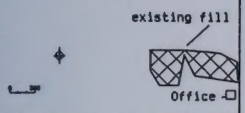
Chapman & Associates, Inc.
Hazard Materials

Well Construction Details

Depth	Soil Classification	Description
0		
10		
20		
30		
40		
50		

Boring Name: SI-3

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: air rotary
Drilling Firm: Four-Star Drilling, Lewistown
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
55		becomes less arenaceous with depth
60		grey-green shale
65		red to maroon clay shale interbedded with grey shale and grey green shale
70		yellow fine-grained sand and grey silt grey-green, medium-grained sandstone, well indurated
75		loose sand and silt ranging in color from rust to grey-green
80		
85		
90		grey-green, fine-grained silty sand with some rust zones and thin silty clay beds; becomes finer with depth to sandy silt and clay
95		
100		

4045
4040
4035
4030
4025
4020
4015
4010
4005
4000

Boring Name: SI-3

Job Number: 03-SI

Client: Sanborn, Inc.

Date: 10/4/03

Drilling Method: Air rotary

Drilling Co.: Fern Air Drilling Locations

Total Depth: 200 ft.

Top Elevation:

Boring Logged: Sanborn

Geologic Description

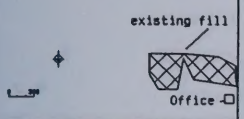
Water Level

Depth

Geologic Cross Section

Well Construction Details

Sanborn & Associates, Inc.
Helena, Montana



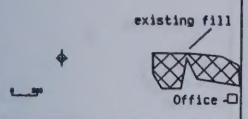
Boring Name: SI-3

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: air rotary
Drilling Firm: Four-Star Drilling, Lewistown
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description	Elevation
			3995
105			3990
110		light grey argillaceous sandstone	3985
115		maroon shale	3980
		dark grey clay shale	
120			3975
125		maroon shale punctuated by thin strata of sandy grey-green shale	3970
130			3965
135		hard, sandy grey-green shale	3960
		maroon shale	
140			3955
		sandy, grey-green shale	
145		maroon shale	3950
		grey-green shale	
		well-indurated, shaley, grey-green sandstone, poor return at 150 feet	
150			



Boring Name: SI-3

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: air rotary
Drilling Firm: Four-Star Drilling, Lewistown
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
155		
		maroon shale
		hard, grey, sandy shale and shaley sandstone, poorly indurated and more argillaceous approaching 160 feet
160		no return
165		maroon shale, variably lithified
170		
175		sticky red and maroon shale
180		
185		no return; injected water to clear hole; mostly sticky shale blown out; saturated at 185'
190		
195		
200		dark grey, limey (?) shale, very hard

3945
3940
3935
3930
3925
3920
3915
3910
3905
3900

Boring Name: B1-3

Job Number: 95-91
Client: Sanitation Dev. Zone
Date: 10/6/93
Boring Method: Auger
Boring Fee: Low-Star Drilling Company
Total Depth: 200 ft
TEC Engineer:
Geologist: Shepherd

Boring Plan

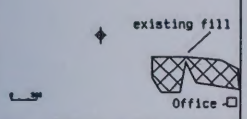
Geologic Log

Depth (ft)

Description

Well Construction Details

Geotechnical & Associates, Inc.
Hartford, Montana



Boring Name: SI-4

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: Air Rotary
Drilling Firm: Four Star, Lewistown, MT
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
0		tan silty loam
		yellowish-tan sandy silt
20		rusty, sandy silt
		greyish-tan silt grading to dark grey and black shale
30		yellow sandy silt interbedded with grey sandy silt
35		grey-green silty sandstone with a few yellow sand/silt beds
50		

4070
4065
4060
4055
4050
4045
4040
4035
4030
4025

Boring Name: ST-4

Job Number: 93-01
Client: Tantalus Inc. Corp.
Date: 10/6/93
Drilling Method: 4¼ Hollow
Drilling Firm: Fine Star Lowerlows, NY
Total Depth: 200 ft
Top Elevation:
Geologist: Shepard

Description

Sandy loam

Yellow-brown sandy silt

Dusty, loamy soil

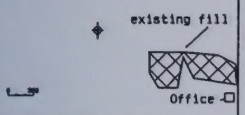
Grayish-tan silt grading to dark gray and black sand

Yellow sandy silt interbedded with gray sandy silt

Gray-green silty sandstone with a few yellow sandy/silt beds

Boring Name: SI-4

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: Air Rotary
Drilling Firm: Four Star, Lewistown, MT
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
55		
60		grey-green silty sandstone with intercalated beds of rusty yellow sandy silt; yellow silt strata are less than a foot thick and occur every three to five feet
65		
70		
75		
80		
85		maroon shale
90		
95		
100		

4020
4015
4010
4005
4000
3995
3990
3985
3980
3975

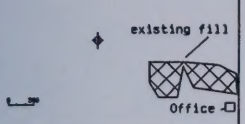
Boring Name: SI-4

Job Number: 13-SI
Client: Destination, Inc., Elgin
Date: 8/6/13
Drilling Method: Air Rotary
Drilling Firm: Fox Star, Lewiston, MT
Total Depth: 200 ft.
TOC Elevation:
Geologist: Seymour

Description & Remarks, Inc. Hydros. Monitors

Well Design Option Details

Depth	Drilling Rate	Description
0		
20		
40		
60		
80		
100		



Boring Name: SI-4

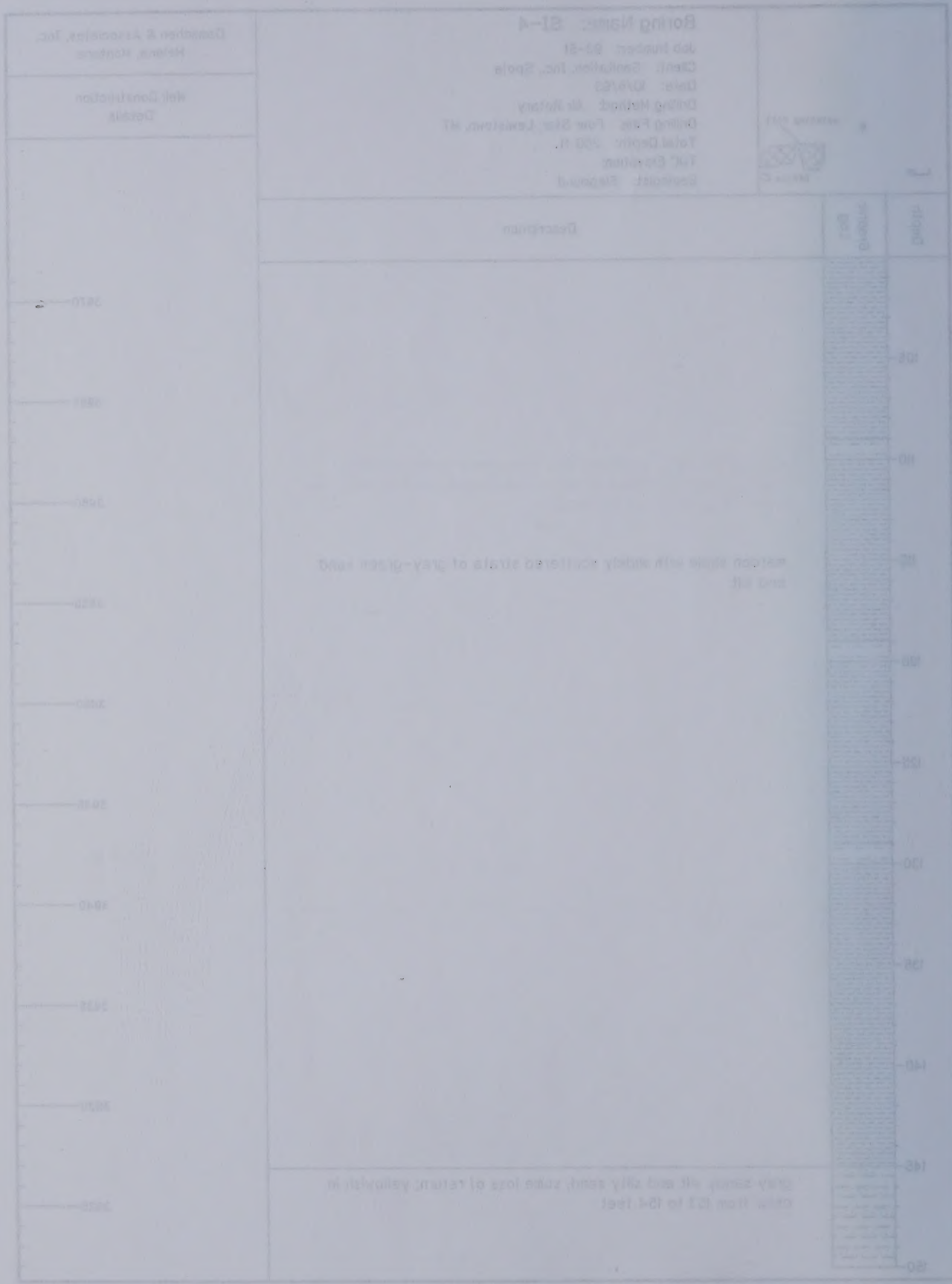
Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: Air Rotary
Drilling Firm: Four Star, Lewistown, MT
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund

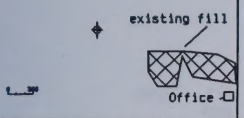
Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
105		maroon shale with widely scattered strata of grey-green sand and silt
110		
115		
120		
125		
130		
135		
140		
145		grey sandy silt and silty sand, some loss of return; yellowish in color from 153 to 154 feet
150		

Well Construction Details
3970
3965
3960
3955
3950
3945
3940
3935
3930
3925





Boring Name: SI-4

Job Number: 93-51
Client: Sanitation, Inc., Spoja
Date: 10/6/93
Drilling Method: Air Rotary
Drilling Firm: Four Star, Lewistown, MT
Total Depth: 200 ft.
TOC Elevation:
Geologist: Siegmund

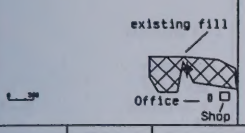
Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description	Elevation
			3920
155			
			3915
160		grey sandy silt over hard, CaCO3-cemented argillaceous sandstone, yellowish green in color	
			3910
165			
			3905
		sandy grey silt	
170			
			3900
175			
			3895
180			
			3890
185			
			3885
190		maroon shale interbedded with thin strata of grey silt and silty clay	
			3880
		slightly sticky	
195			
			3875
200			

Boring Name: SI-5

Job Number: 93-51
Client: Sanitation, Inc.
Date: 1/24/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling, Sidney, MT
Total Depth: 40 ft.
TOC Elevation:
Geologist: B. Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
		fill; sand and gravel
		rusty tan sandstone and siltstone
5		
		tan clay
		buff to rusty brown sand with a few thin silt and clay beds; more clay and silt beds with depth
10		
		dark grey carbonaceous clay shale
15		grey silt
		rust red silty sand, interbedded with thin carbonaceous shale beds at 18-20 feet
20		rusty siltstone
		dark grey carbonaceous clay shale
25		
		white to light grey silt
30		rusty sandstone
		white to light grey silt, rusty at 33'
35		grey-green sandy silt from 33 to 36'
		rusty buff silt and very fine-grained sand
40		
45		
50		

Well Construction Details
4125
4120
4115
4110
4105
4100
4095
4090
4085
4080

Boring Name: S1-5

Job Number: 52-01
Client: Subsidiary, Inc.
Date: 1/14/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling, Sidney, NY
Total Depth: 40 ft.
Top Elevation:
Geologist: B. Shepherd

Description

Dark gray carbonaceous clay shale

Gray silt

Coal and clay shale, interbedded with thin carbonaceous shale

Dark gray carbonaceous clay shale

Shale is light gray silt

Clay stringers

Shale is light gray silt, clay to 32'

Gray-green sandy silt from 32 to 36'

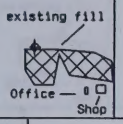
Clay Soil silt and very fine-grained sand

Geophysical Associates, Inc.
Helena, Montana

Log Completed on
Details

Boring Name: SIP-1

Job Number: 93-51
Client: Sanitation, Inc.
Date: 1/23/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling
Total Depth: 40 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

csg 1.25" dia Sch 80

Depth	Graphic Log	Description
0		silty tan clay and clayey silt, interbedded
13		reddish maroon sandy claystone
15		tan sand, fine-grained, loose
		fine-grained, hard, will-indurated sandstone
18		grey sand as above, loose, possibly more fines
20		tan sandy silt, variably indurated, but overall is firm
24		rusty silty sandstone
25		interbedded silt and clay
		rusty sand interbedded with thin clay streaks; sand is limonitic, very fine-grained with ample silt fraction wet silty sand, making a little water
34		wk ~ 34'
35		resistant sandstone; cuttings very wet; saturated
39		black shale
40		
45		
50		

4115
4110
4105
4100
4095
4090
4085
4080
4075
4070

4' ho slotte

est elev 4119

Boring Name: SP-1

Job Number: 03-91

Client: Sanborn Inc.

Date: 7/23/03

Drilling Method: 2in Rotary

Drilling Firm: Boart Drilling

Total Depth: 40 ft.

TOC Elevation:

Geologist: Engineer:

Description & Associates, Inc.
Water Monitoring

Well Construction Details

Description

Sandy lean clay and clayey silt, interbedded

Poorly graded sand, fine - grained, loose

Clay-grained, fine, well-rounded sandstone

Silty sand as above, some possibly more fines

Lean sandy silt, slightly moist-wet, but overall is dry

Fairly silty sandstone

Fine sandstone w/ some clay

Fairly sand interbedded with thin clay stringers, sand is smooth, no clay grained with angle rock (section wet silty sand, making a 3 ton wash)

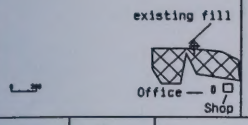
Sandstone sands, cuttings very wet, saturated

Total depth

Boring Name: SIP-2

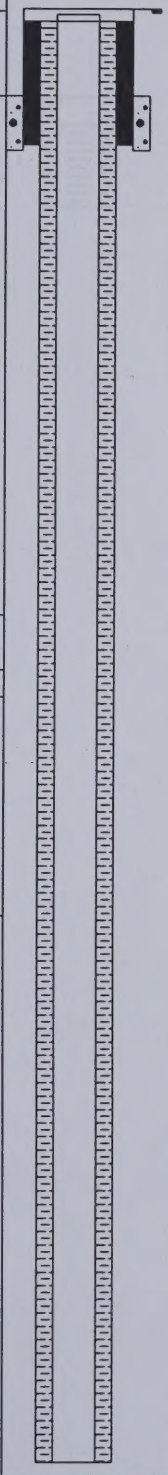
Job Number:
Client: Sanitation, Inc.
Date: 1/23/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling
Total Depth: 54 ft.
TOC Elevation:
Geologist: Siegmund

Damschen & Associates, Inc.
Helena, Montana



Depth	Graphic Log	Description
		sandy siltstone and mudstone
		rusty red very fine-grained sandstone and sandy siltstone
5		fairly hard; turns from light grey to brownish gry
10		rusty
15		interbedded with thin strata of grey clay
20		rusty sandstone, silty, very hard
		Light grey clay shale and rusty sand
25		mostly sandy silt interbedded with sandy clay shale; silt is light grey, clay is medium grey
30		hard grey sandstone, very fine-grained, sucrosic
		rusty sandstone
35		grey sandstone as above
40		loose buff-grey sand
		rusty
		rusty
45		hard sandstone, grey, fine-grained with some limonitic streaks
50		

Well Construction Details



4145
4140
4135
4130
4125
4120
4115
4110
4105
4100

Boring Name: SIP-2

Client: Sandbox, Inc.

Date: 7/13/95

Drilling Method: Air Rotary

Drilling Fluid: Simple Drilling

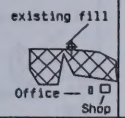
Total Depth: 34.0 ft.

TOC Elevation:

Geologist: Simpson

Boring Name: SIP-2

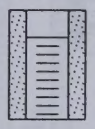
Job Number:
Client: Sanitation, Inc.
Date: 1/23/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling
Total Depth: 54 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

Depth	Graphic Log	Description
		grey and rusty sand with scattered dark grey clay streaks
		cuttings are damp; 10 minute wait produced steam and mud when blown
55		black clay shale



4095 SL
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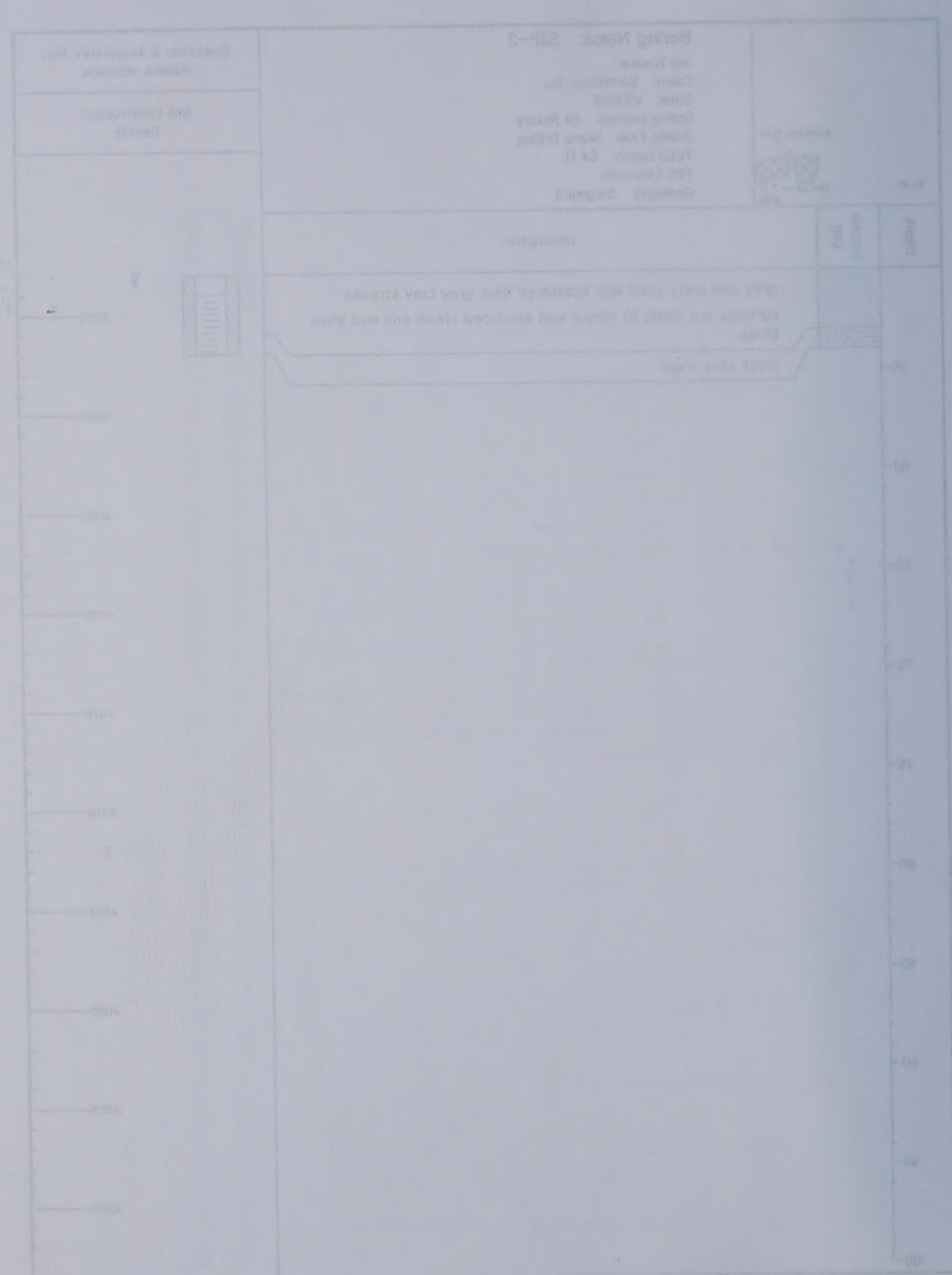
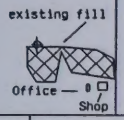


Boring Name: SIG-1

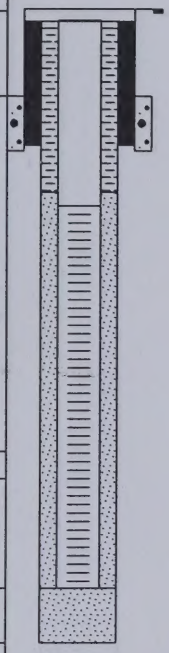
Job Number: 93-51
Client: Sanitation, Inc.
Date: 1/23/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling, Sidney, MT
Total Depth: 18 ft.
TOC Elevation:
Geologist: B. Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details

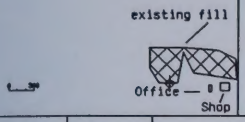
Depth	Graphic Log	Description
0–13		silty tan clay and clayey silt, interbedded
13–14		reddish maroon sandy claystone
14–18		tan sand, fine-grained, loose fine-grained hard sandstone loose grey sand
18–20		tan sandy silt, variably indurated, but overall is firm



Depth	Elevation
5	4115
10	4110
15	4105
20	4100
25	4095
30	4090
35	4085
40	4080
45	4075
50	4070

Boring Name: SIG-2

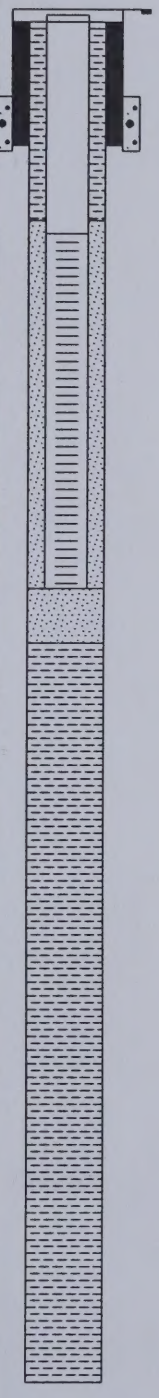
Job Number:
Client: Sanitation, Inc.
Date: 1/24/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling
Total Depth: 47 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

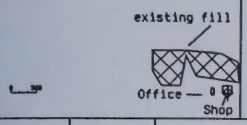
Well Construction Details

Depth	Graphic Log	Description
		dirt fill
		greyish-tan silty claystone and clayey siltstone with some thin fine- grained sand beds
5		
		very fine-grained brown sand
		dark grey clay shale
10		rusty yellow and reddish sandstone and sand
15		soft grey-tan clay shale with thin beds of buff sand
		interbedded silt and sand
20		resistant grey sandstone
		very dark grey clay shale
25		dark red, hard silty sandstone
		sandy silt with minor clay beds grading to silty sand at 28 feet
		buff to yellow brown, silty, very fine-grained, loose sand
30		a few very dark grey clay shale beds occur at 30 to 33 feet
35		reddish sandstone
		predominately buff sandy silt with thin intercalated clay strata
40		resistant gry claystone and tan sand 41 to 43 feet
		grey clay shale with minor sand dark grey clay beds interspersed
45		
50		



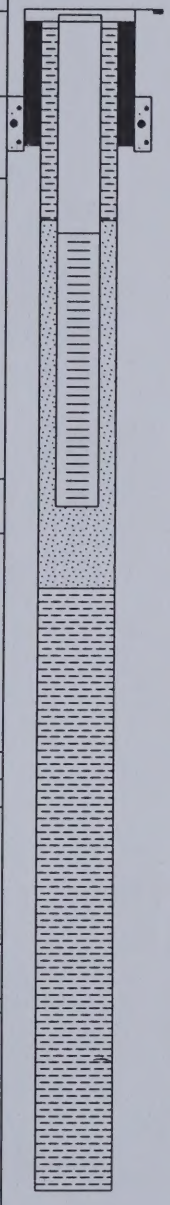
Boring Name: SIG-3

Job Number:
Client: Sanitation, Inc.
Date: 1/24/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling, Sidney, MT
Total Depth: 40 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details



Depth	Graphic Log	Description
		fill; black clay shale and river gravel
5		black clay shale with rusty partings and fracture faces
10		
15		light grey claystone
		grey-brown sandy silt and siltstone; ample gypsum
20		scattered grey clay beds from 20 to 24 feet
25		dark grey clay shale
		buff silt underlain by <0.5' silty limestone
		sandstone and silty sand with scattered clay shale beds
30		grey clay shale
		tan sand
35		grey clay shale, rusty at 35 feet
40		
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50		

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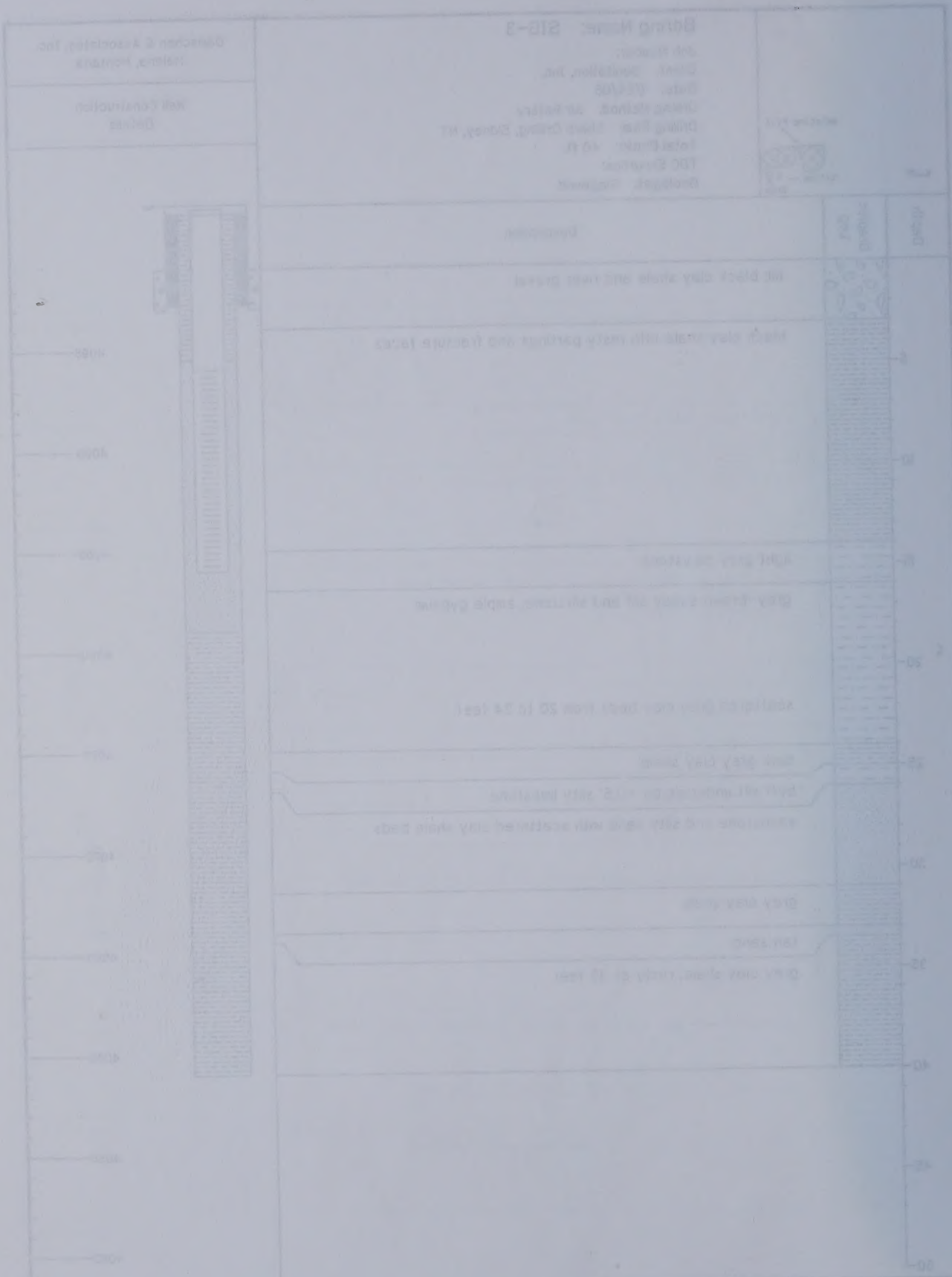
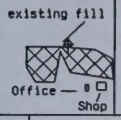


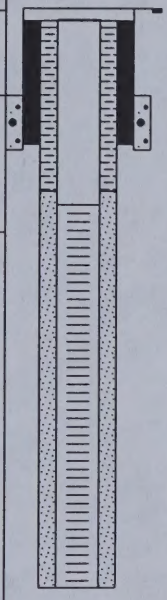
Boring Name: SIG-4

Job Number: 93-51
Client: Sanitation, Inc.
Date: 1/24/95
Drilling Method: Air Rotary
Drilling Firm: Sharp Drilling
Total Depth: 18 ft.
TOC Elevation:
Geologist: Siegmund



Damschen & Associates, Inc.
Helena, Montana

Well Construction Details



Depth	Graphic Log	Description
5		sandy siltstone and mudstone
10		rusty red very fine-grained sandstone and sandy siltstone fairly hard; turns from light grey to brownish gry rusty
15		interbedded with thin strata of grey clay
20		
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4130
4125
4120
4115
4110
4105
4100